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astronomy, increasing returns constitute the rule and not the exception, while the methods of securing the maximum efficiency by the principles of "scientific management" may be as successful in an observatory as in an industrial establishment.

An illustration of my meaning is presented by the photometric work at Harvard. In 1879 an instrument was constructed for measuring the light of the bright stars, with telescopes two inches in diameter. With this, during the next three years, a hundred thousand measures were made of four thousand stars, mainly visible to the naked eye. When people asked me if we had the largest telescope in the world, I would answer, "No, but we have the smallest that is doing useful work." Encouraged by the success attained, a second similar instrument was constructed with telescopes of four inches aperture. Since 1882 over a million measures have been made of nearly fifty thousand stars. Three times it has been sent to South America to measure the southern stars, and it is now on its way to South Africa, loaned to an English astronomer. To study still fainter stars a twelve-inch telescope has been mounted, and with this since 1892 I have made seven hundred thousand measures of about forty thousand stars. The results fill ten of the quarto volumes of the *Annals* of the observatory, and furnish a standard scale of magnitude from the first to the twelfth magnitude for stars from the north to the south pole.

An excellent example of organization is furnished by the work of the International Astronomical Society. The great astronomer Argelander proposed to determine the exact places of a hundred thousand northern stars. Seventeen observatories took part, including two in America, Harvard and Albany. In extending the work to the southern stars, Harvard again took a zone. Each zone occupied an observer and a corps of assistants for nearly a quarter of a century. The results of both fill half a dozen volumes of the *Annals* and the cost in salaries alone was about two hundred thousand dollars.

May we see some of the great problems in astronomy solved at the Allegheny Observatory better than ever before, and the work repeated on star after star until the entire field has been successfully covered.

Edward Charles Pickering
Harvard College Observatory

THE RESPONSIBILITIES OF AN OBSERVATORY STAFF[1]

It falls to me in these dedicatory exercises to say a few words on behalf of the observatory staff, into whose keeping these fine instruments are for the time being placed. You may be sure that we have given much thought to deciding how we might best fulfill this trust, and it is natural that the same question should be a prominent one in the minds of all those who are interested in the welfare of this institution. We are doubtless all agreed that our observatory has not been erected for the purpose of enhancing the reputation of any individual or individuals, nor to enhance the reputation of the observatory itself, nor of the university of which the observatory is the astronomical department. These things are much to be desired in themselves, and we hope that they may come to pass; but if they do come to pass it must be only incidentally, and nothing of this kind must be allowed to obscure the goal toward which we are striving; namely, to add as much as we can to the progress of our science; or, to use the words that were often in the mouth of the

[1] An address delivered at the dedication of the new Allegheny Observatory, August 28, 1912.

first chairman of our observatory committee, "to push forward the frontier of human knowledge."

In the minds of many whose interest in astronomy is general rather than special, we often find the belief that it is the principal business of the astronomer to make discoveries. It is true that there is hardly anything more striking that the astronomer can do than to bring to the attention of the world a new comet, a temporary star, or the like. But valuable as such discoveries are, they do not constitute the kind of work that will most rapidly push forward the frontier of human knowledge. I would, if I might, place an inscription above the door of this observatory and would call to it the attention of each new member of our staff, "Abandon hope of making discoveries, all ye who enter here." This view may seem a radical one to part of my audience, but I am sure that it will meet with ready sympathy among those astronomers here present who have had occasion to give thought to this subject. Some years ago, Professor Cattell, the editor of SCIENCE, asked ten of our leading astronomers to set down in the order of their preference the names of those living Americans who had contributed most to the progress of astronomy. One result of this ballot was very remarkable; it was found that the voters had without exception put the same name at the head of their lists—that of Simon Newcomb. This high place in the esteem of his colleagues was reached by setting on foot and directing the exceedingly laborious computations that would enable us to predict the situations of the sun, moon, planets and some of the fixed stars, with greater accuracy than had hitherto been the case; or, in other words, by following out with greater thoroughness, the consequences of the law of gravitation within the solar system. To this, the principal work of his life, Newcomb continued to add other important investigations up to the day of his death; but throughout his long and fruitful career we find no record of a discovery. Be it well understood that I am using this word with its narrower meaning, and not in the sense that would permit us to speak of Kirchhoff as having discovered the principle of spectrum analysis, or of Langley as having discovered a method of mapping the entire spectrum of the sun.

Let me give one other illustration of what work it is that astronomers themselves deem to be the best. Near the little village of Nyack there lives in modest retirement upon the farm of his fathers and of his own boyhood, George William Hill. Although he is perhaps the greatest genius that this country has as yet borne, it is safe to say that not one person in a thousand, even among people of education, is familiar with his name, much less with his work. But among astronomers, both abroad and at home (possibly more abroad than at home), he is recognized as being one of a very few to whom astronomy of the present day owes most. Here again discoveries form no part of this notable career; and in fact so far as records go, Hill may never have used a telescope. His greatest work is in connection with periodic orbits, the best method yet devised for handling the problem of three bodies under certain restrictions.

You are not getting the impression, I trust, that I wish to belittle the work of discovery. I am merely trying to get the bearing of such work so far as it affects the responsibilties of an observatory staff, at whose disposal have been placed instruments of the first rank. You must first catch your comet before you can make comet investigations, and so with asteroids, double stars and spectroscopic binaries.

Statistical investigations concerning all four of these classes of bodies have recently been made; they constitute additions of the most desirable kind to our stock of knowledge, and have done much to indicate in what directions further additions are to be sought. Apart from all this, if the discovery of a comet (for example) were not otherwise useful, it would frequently justify itself by calling attention to men of promise. It was in this way that the astronomical world has come to have the benefit of the extraordinary talents of Edward Emerson Barnard. With a little telescope purchased out of the meager earnings of his youth, he discovered in rapid succession a surprising number of faint comets. The attention thus attracted to him soon resulted in an appointment at the Lick Observatory, and later one at the Yerkes Observatory, so that he has had access to some of the most powerful instruments in the world. He has used these instruments to excellent purpose and with a diligence that has rarely been equalled; but it is significant that in the past twenty years he has made no further discoveries. In a case like this it would be more to the point to speak of the comet as having discovered the man, than of the man as having discovered the comet.

We are often told that an astronomer pointing his telescope more or less at random to the sky and faithfully recording what he sees or photographs, is bound to add something to our fund of knowledge. While this is true, promiscuous observing is to be encouraged only if nothing else is possible, and is surely never to be encouraged within an observatory. The fact is that astronomy of to-day demands answers to definite questions; the astronomer who goes to his telescope without having one of these questions in mind is at least partially wasting his time. In other words an observatory staff should regard their profession as a branch of engineering, in which the problems to be solved are quite as definite as those, for example, that confront the civil engineer. If this seems to you to be a somewhat dry view to take of so beautiful a subject as astronomy, I would remind you that none save engineers are especially interested in the plans and specifications for a bridge, but that all of us can take delight in the finished structure, either for its utility or its beauty. In the same way the methods employed by the astronomer are almost always of very special interest, while the results of his work appeal to us all as educated men and women. How long will the sun continue to be sensibly as bright and as hot as it is now? How does our sun compare in size and glory with other stars? How comes it that some stars are double, while others (our sun among them) are single? How are the stars distributed in space? What causes some stars to vary in brightness? These are some of the questions to which astronomers are seeking the answers, and the results of these inquiries will surely interest you as deeply as they do the astronomer himself.

Let me now state briefly what specific use we intend to make of our various instruments. Under the north dome is the Keeler memorial reflector, having an aperture of thirty inches. This telescope and the Mellon spectroscope attached to it have been in constant use during the past six years in the prosecution of a single research, the determination of the orbits of spectroscopic binaries. This work we shall continue as long as it remains profitable to do so. Under the same dome is a vertical or tower telescope of nine inches aperture and twenty-nine feet focal length. This is "fed" by a cœlostat mirror on the mount-

ing for the Keeler reflector, and attached to the telescope is a powerful solar spectrograph, the gift of Mr. H. K. Porter. With these we are taking part in the spectroscopic determination of the solar rotation, a project that was set on foot at the last meeting of the International Solar Union, and in which six observatories, in this country and abroad, are cooperating.

Under the southeast dome is the thirteen-inch visual refractor that formed the nucleus around which the old observatory was built. Once the third largest telescope in the world, it has now become the third largest in our observatory. This telescope we now use chiefly for the instruction of the public; with the lecture hall below it (used on cloudy evenings) it forms a public observatory, the privileges of which are freely offered to the people of Pittsburgh. So eagerly has this offer been accepted, that two years ago we found it expedient and possible to extend this work, and to pledge ourselves to continue it in perpetuity.

Attached to the thirteen-inch refractor is a four-inch camera, used to determine the brightness of stars by the extra-focal method. The observing program is made up chiefly of stars that we are observing at the same time with the spectrograph.

In one of the basement rooms on the north side of the building a ten-inch photographic telescope is mounted in a fixed position on an inclined pier and directed toward the north pole of the heavens. The work with this instrument is of an experimental character. If its outcome should be favorable we hope to undertake, probably in cooperation with the Harvard College Observatory, the compilation of a catalogue of faint stars by entirely new methods.

At the west end of our building is a four-inch transit instrument with which we are still maintaining the extensive time-service installed by Langley in 1869. As auxiliaries to this instrument we have three second-pendulum clocks. One of these is a Riefler clock maintained under constant pressure and temperature, and this proves to be a time-piece of unusually accurate performance.

Lastly we come to the Thaw memorial telescope, under whose dome we are assembled this afternoon. Last summer when we fixed the date for this dedication, we thought that this telescope would be quite complete by to-day; but it appears that at least another year must elapse before the objective can be ready. This is due to the difficulty of securing a suitable disk of flint glass, the crown disk having been delivered some months ago. The aperture of the telescope is to be not less than thirty inches, and unlike most other refractors of the largest size, it is to be primarily a photographic instrument. A twelve-inch correcting lens is to be provided; it will be a matter of only a few seconds to put it into the optical axis, thus changing the color curve into one that will be suitable for visual observations. The mounting has all those appurtenances (and no other) that modern practise has shown to be desirable. Throughout its design and construction, efficiency for astrometric work was the chief object in view.

With the Thaw telescope we contemplate an attack upon three problems; first, the accurate determination of the distances of many stars. How extensively we shall go into this work will depend upon the activities of certain other observatories that have declared similar intentions. But the need of such determinations is one of the most pressing in astronomy and it is likely that the telescope before us can be profitably occupied in this work for many years to come. Secondly, we owe it to our suc-

cessors of perhaps a hundred years hence to determine with great accuracy the relative places of stars that form globular clusters. It is only in this way that we shall ever be able to say what the motions within these clusters are; and this in turn will go far toward telling us what these objects themselves are, and what place they occupy in the universe of stars. A third research that we contemplate is the determination of the brightness of faint stars by means of extra-focal images, or otherwise expanded star disks. This method for determining stellar magnitudes is surpassed in accuracy only by the selenium photometer, which is however not applicable to faint stars.

These are the things that we have in mind, but we reserve the right to alter these intentions as soon and as often as circumstances may demand. I should not wish to commit myself, much less any other man, to an unalterable routine of work. But I do wish that it were in my power to commit the present staff and its successors to the policy of doing that thing which is most in need of attention, within the limits set by our resources and equipment, both personal and instrumental. If we do not succeed in contributing our fair share to the progress of our science, I think it will not be because we have not tried; and I believe I can make this promise for those who are to come after us, as well as for ourselves. For it would be a strange thing if the devotion that has been lavished upon the Allegheny Observatory by William Thaw and his sons, by Langley, Keeler, Wadsworth and Brashear—it would be a strange thing, I say, if the example of such devotion should ever cease to be a compelling incentive to any who may have the privilege of working within these walls, and if the tree that these men have planted and nourished should cease to bear fruit for many a season to come.

FRANK SCHLESINGER
ALLEGHENY OBSERVATORY

M. HENRI POINCARÉ

THE city of Paris is commonly regarded as the greatest mathematical center of the world, and Henri Poincaré stood for a number of years at the head of the Paris mathematicians. He was a mathematician in the broadest as well as in the deepest sense of this term. He started as an engineer in 1879, but soon thereafter he entered upon his life work as university instructor, first at Caen in December, 1879, and afterwards at Paris from October, 1881, until his death on July 17, 1912. His positions in the University of Paris were as follows: Maître de conferences d'analyse, chargé du cours de mécanique physique et expérimentale; professeur de physique mathématique et de calcul des probabilités, and professeur d'astronomie mathématique et de mécanique céleste.

He was born at Nancy, April 29, 1854, and was educated successively at the Lycée de Nancy, l'École Polytechnique and at l'Ecole nationale supérieure des mines, receiving his doctor's degree from the University of Paris in 1879. He was a very bright student and received first rank at the entrance examination of l'Ecole Polytechnique. At the early age of 32 he was elected as a member of l'Académie des Sciences, and for this occasion he prepared, in 1884, a statement entitled "Notice sur les travaux scientifiques de M. Henri Poincaré."

Although this "Notice" was written less than five years after Poincaré had begun the publication of his researches, it reviews a large number of his published articles along the following three lines: (1) Differential equations, (2) General theory of functions, (3) Arithmetic or the theory of numbers. He emphasizes the fact that he did not pursue his researches in these three directions independently of each other, but that the results obtained along these various lines threw light on each other, and that his work along each